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Rest–Redistribution Thallium-201 Scintigraphy to Determine Myocardial Viability Early After Myocardial Infarction

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Objectives. **This study attempted to determine the utility of early rest–redistribution thallium-201 imaging in detecting residual myocardial viability after myocardial infarction.**

Background. **The early detection of myocardial viability after myocardial infarction would have clinical relevance.**

Methods. **Thirty-one patients with acute myocardial infarction had early (mean [±SD] 2 ± 1 day) rest–redistribution thallium-201 imaging followed by radionuclide and coronary angiography. Late studies included stress–redistribution–reinjection thallium-201 imaging or radionuclide angiography, or both. Viability was defined by the rest thallium-201 scan as an initial mild rest defect or any defect that demonstrated redistribution.**

Results. **Group 1 (n = 15) was predicted to have viable and Group 2 (n = 16) nonviable myocardium in the infarct zone. Group 1 patients were more likely to have a patent infarct-related artery (15 of 15 vs. 10 of 16, $p < 0.03$), higher initial ejection fraction (61 ± 12% vs. 53 ± 9%, $p < 0.05$), higher infarct wall motion score ($p < 0.0001$) and fewer abnormal thallium-201 segments ($p < 0.0001$). On follow-up studies, ejection fraction improved in Group 1 (from 57 ± 13% to 66 ± 10%, $p < 0.05$, n = 9) and deteriorated in Group 2 (from 53 ± 10% to 46 ± 8%, $p < 0.05$, n = 13). On late stress testing with thallium-201 reinjection, Group 1 patients had fewer abnormal segments ($p < 0.03$) and higher infarct zone counts during exercise ($p < 0.05$) and after reinjection ($p < 0.05$) than Group 2 patients.**

Conclusions. **If confirmed by larger studies, early rest–redistribution thallium-201 imaging may be a useful technique for identifying residual viability after myocardial infarction.**

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After acute myocardial infarction, myocardial stunning may cause reversible left ventricular dysfunction as opposed to the irreversible damage caused by necrosis (1). Regional and global left ventricular function may then improve over time or with revascularization. Because there is an uncoupling between regional myocardial perfusion and contraction in this setting, assessment of ventricular function and vascular patency may be insufficient to assess myocardial viability (1,2).

Thallium-201 reinjection after stress–redistribution imaging is useful in demonstrating myocardial viability in patients with chronic coronary artery disease (3–9). In these patients, myocardial thallium-201 uptake is a marker of both regional perfusion and viability. Because stress testing is not appropriate in the first few days after myocardial infarction (10), the current study was designed to define the utility of early rest–redistribution thallium-201 imaging in detecting myocardial viability early after acute myocardial infarction.

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Methods

Patient selection protocol. Thirty-one patients with an acute Q wave myocardial infarction were prospectively enrolled after giving written informed consent. The patients and their physicians agreed to obtain an initial rest thallium-201 scan and radionuclide angiogram early after infarction and at least one follow-up study, either a radionuclide angiogram or a low level exercise thallium-201 stress test. Many of these tests other than the rest thallium-201 scan are routinely ordered for postinfarction patients at our institution. Infarction was diagnosed by typical chest pain, characteristic abnormal findings on the electrocardiogram (ECG) and an increase and decrease in cardiac creatine kinase MB isoenzyme (CK-MB) levels. Patients with cardiogenic shock or requiring emergent catheterization were excluded. Patient management during the hospital stay was unaffected by enrollment in the protocol. Thrombolytic therapy was administered to 22 patients. Seventeen patients had myocardial revascularization with either coronary angioplasty (n = 13) or coronary bypass surgery (n = 4). The infarct-related artery was revascularized in each patient. Patients were selected for revascularization by the attending physicians without knowledge of the rest thallium-201 scan results.

Thallium-201 imaging. Patients were injected with 2.5 mCi thallium-201 at rest at a mean [±SD] of 2 ± 1 days after infarction. Planar imaging using a conventional gamma camera

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(GE Starcam) and a general all-purpose collimator was used. A symmetric 20% window centered around the 68- to 80-keV mercury X-rays and a 10% window on the 167-keV peak were used. The initial set of images was obtained 5 min after thallium-201 injection. Images were acquired for 5 min (~500,000 counts/image). All images were stored on a computer disk in a 128 × 128-matrix format for later processing. The first image was obtained in the view that gave best septal separation. The camera was then rotated 45° (right anterior oblique) and then 30° (left anterior oblique) from the best septal view. A second set of images was obtained 4 h after the initial images in the same positions, with 5-min acquisition times for each view.

Patients undergoing predischarge low level stress testing were injected with 2.5 mCi of thallium-201 1 min before the termination of exercise. After redistribution imaging, the patients were reinjected with 1 mCi of thallium-201, and a third set of images were obtained. Similar to the sequence described for the rest study, three views were obtained. Data for each stress image were acquired for a preset number of counts (400,000). Redistribution and reinjection scans were acquired for a similar time as the exercise image.

Qualitative thallium-201 analysis. The thallium-201 scans were interpreted by a nuclear cardiologist with no knowledge of the clinical data. Each view was divided into three segments. The nine segments were then graded for thallium-201 uptake on a 0 (absent uptake) to 3 (normal uptake) scale. Redistribution was considered present when there was an improvement ≥1 in the segments with an initial defect. After this blinded interpretation, the infarct zone was identified using the angiographic data. Appropriate thallium-201 segments in the three views were then assigned to the infarct zone.

Quantitative thallium-201 analysis. Quantitative analysis involved modified bilinear interpolative background subtraction and standard nine-point smoothing according to previously described techniques (11). From these images, circumferential maximal count profiles were obtained, as described previously for exercise studies (12,13). The curves for the initial and delay images (and reinjection images for the exercise studies) were normalized so that the maximal pixel intensity was equal to 100%. Using the qualitative image interpretation, the infarct zone on each initial image was located. The 18° segment with the lowest counts within the infarct zone was identified. The same segment was analyzed on the delay (and reinjection) study. In views in which the infarct was not identified qualitatively, counts were not recorded.

Radionuclide angiography. Radionuclide angiography was performed in all patients 3 ± 2 days after infarction. The patients' red blood cells were labeled with 25 mCi of technetium-99m by the in vivo technique. A gamma camera (GE Starcam) equipped with a low energy all-purpose parallel-hole collimator was positioned in the left anterior oblique position, which gave best septal separation. The camera was then rotated 45° (right anterior oblique) and then 30° (left anterior oblique) from the best septal view. In each view, studies were acquired for 3,000 counts/pixel in the center of the left ventricle. Gated equilibrium radionuclide angiograms were obtained in a 36-frame/cycle format. The studies were analyzed using a semiautomatic program that generated regions of interest over the left ventricle in the best left anterior oblique view. From the regions of interest, a background-corrected time-activity curve was generated from which ejection fraction was calculated. Similar to the thallium-201 study, each view was divided into three segments for analysis of regional wall motion. The nine segments were graded using the following scale: −1 = dyskinetic; 0 = akinetic; 1 = moderately to severely hypokinetic; 2 = mildly hypokinetic; 3 = normal. After blinded review, the infarct zone was identified. The segment within the infarct zone with the best and worst wall motion was recorded. A similar acquisition, processing and scoring system was utilized for the second radionuclide angiograms acquired late after infarction (n = 22).

Coronary angiography. All patients underwent coronary angiography using the standard Judkins technique 2.7 ± 2.4 days after infarction. Multiple oblique projections were obtained, and the major coronary arteries and their branches were independently examined by two angiographers without knowledge of the results of the noninvasive tests. Maximal lumen diameter narrowing for each major coronary artery was estimated visually, and stenoses were considered significant if there was >50% reduction in diameter. Each patient was classified as having one-, two- or three-vessel coronary artery disease.

Exercise protocol. Predischarge low level exercise testing was performed by 15 patients using the Naughton protocol. Patients exercised for a maximum of 5 metabolic equivalents (METS) or to a peak heart rate of 70% of age-predicted maximum. The test was terminated prematurely for angina, ST segment depression, serious arrhythmias or a decline in systolic blood pressure or if the patient could no longer exercise because of fatigue or dyspnea.

Definition of viability. On the basis of the initial thallium-201 rest–redistribution images, viability in the infarct territory was prospectively defined as an initial defect that was mild (<50% reduction in maximal thallium-201 activity) or a defect of any severity that exhibited an increase in counts ≥15% on delayed images, representing redistribution (Group 1). This degree of redistribution has predicted improved perfusion postoperatively consistent with myocardial viability on rest planar imaging (14). Predicted nonviability in the infarct zone was defined as a severe defect, with a >50% reduction in maximal thallium-201 uptake on the initial scan and no evidence of redistribution (Group 2).

Statistical analysis. Differences between Groups 1 and 2 were analyzed using parametric and nonparametric statistical tests. The Student *t* test and Mann-Whitney *U* test were used to evaluate group differences. Repeated-measures analysis of variance was used to determine changes in radionuclide variables over time within the same patient. A Student-Neuman-Keuls test was used to detect differences when the analysis of variance showed significant differences. Two-tailed Fisher exact tests and chi-square procedures were performed to test for

Table 1. Clinical Findings

	Group 1 (predicted viable myocardium) (n = 15)	Group 2 (predicted nonviable myocardium) (n = 16)
Age (yr)	58 ± 12	65 ± 9
Gender (M/F)	14/1	14/2
Infarct location		
Anterior	5	6
Inferior	10	10
Q wave on ECG	11	15
Thrombolytic therapy	12	10
Peak CK (IU/liter)	1,483 ± 1,352	2,810 ± 1,884*
Extent of CAD		
1 vessel	5	9
2 vessel	8	5
3 vessel	2	2
Infarct-related artery		
LAD	5	6
LCx	3	5
RCA	7	5
% Stenosis	90	89
Patent infarct-related artery	15	10†
PTCA/CABG	8/3	5/1‡

*$p < 0.05$, †$p < 0.01$, ‡$p = 0.1$ for Group 1 versus Group 2. Data presented are mean value ± SD or number of patients. CABG = coronary artery bypass graft surgery; CAD = coronary artery disease; CK = creatine kinase; ECG = electrocardiogram; F = female; LAD = left anterior descending artery; LCx = circumflex coronary artery; M = male; PTCA = coronary angioplasty; RCA = right coronary artery.

Table 2. Early Radionuclide Angiography and Rest Thallium-201 Scintigraphy

	Group 1 (predicted viable myocardium)	Group 2 (predicted nonviable myocardium)	p Value (ANOVA)
Radionuclide angiography			
LVEF (%)	61 ± 12	53 ± 9*	
Regional wall motion			
Best segment	2.0 ± 0.6	0.6 ± 0.9*	< 0.0001
Worst segment	1.5 ± 1.1	−0.2 ± 0.7*	
Rest thallium-201 scintigraphy			
Qualitative thallium-201 uptake (114 abnormal segments)			
Abnormal segments/pt	2.6 ± 1.3	4.7 ± 1.5†	
Initial uptake	1.3 ± 0.8	0.42 ± 0.62*	< 0.0001
Delayed uptake	2.0 ± 0.9‡	0.48 ± 0.69*	
No. of segments with redistribution	25/40	4/74§	
Quantitative thallium-201 uptake			
Initial uptake (%)	46 ± 14	31 ± 10	< 0.0001
Delayed uptake (%)	54 ± 16‡	29 ± 11*	

*$p < 0.05$, †$p < 0.0001$ for Group 1 versus Group 2. ‡$p < 0.05$ initial versus delayed uptake. §These four segments did not reach our quantitative criteria for viability with a mean increase in counts of 7 ± 5%. Data presented are mean value ± SD or number of segments. ANOVA = analysis of variance; LVEF = left ventricular ejection fraction; pt = patient.

categoric variable differences between the groups. A p value <0.05 was necessary to achieve statistical significance.

Results

Patients (Table 1). There were 15 patients in Group 1 and 16 in Group 2. There were no differences with respect to the presence of ECG Q waves, treatment with thrombolytic therapy, infarct-related artery location and percent stenosis or number of patients who underwent revascularization. Group 1 had a lower mean peak creatinine kinase level. All patients in Group 1 had a patent infarct-related artery compared with 10 of 16 in Group 2.

Initial postinfarction studies. *Radionuclide angiography (Table 2).* The initial left ventricular ejection fraction was greater in Group 1 than in Group 2. Similarly, mean initial wall motion score in both the best and worst infarct segments were better in Group 1 (predicted viable) than in Group 2 (predicted nonviable).

Rest thallium-201 scintigraphy (Table 2). Of 279 segments on the initial rest thallium-201 images (9 segments/patient), 114 were judged abnormal by qualitative assessment. In Group 1, the number of abnormal segments was lower, and the mean thallium-201 uptake score in the infarct zone on the initial and delay rest images was higher, compared with that in Group 2. By quantitative assessment, the initial mean counts in the infarct zone by definition were different. On delayed imaging, there was an increase in counts in Group 1 only. In Group 1, 10 patients were deemed to have viable myocardium by a ≤50% reduction in initial thallium-201 uptake in the infarct zone, whereas 5 had severe initial defects with thallium-201 redistribution. In Group 2 patients, quantitative thallium-201 uptake did not change between initial and delayed images.

Late postinfarction studies (Table 3). *Exercise thallium-201 scintigraphy.* The low level stress test was performed in 15 patients at a mean of 8 ± 2 days after infarction. All six Group 1 patients exercised for 15 min compared with three of nine Group 2 patients ($p < 0.05$). Only one Group 1 patient had ST segment elevation in the infarct zone on the ECG during exercise compared with four of nine Group 2 patients. Peak heart rate and blood pressure during exercise were similar between the groups. A total of 135 segments were analyzed during stress, redistribution and reinjection. There were fewer abnormal segments and a greater qualitative uptake score in the infarct zone in Group 1 than in Group 2. No segment in Group 2 showed improved uptake on redistribution or reinjection. By contrast, all six patients (10 segments) in Group 1 had evidence of increased uptake after redistribution or reinjection. In three patients (five segments), increased uptake was evident by redistribution; in one patient (two segments) it was evident only after reinjection and in two (three segments), there was partial uptake on the redistribution scans with further normalization after reinjection. By quantitative assessment, the mean initial thallium-201 uptake in the infarct zone after exercise was also greater in Group 1 than in Group 2. After redistribution and thallium-201 rein-

Table 3. Late Postinfarction Studies

	Group 1 (predicted viable myocardium)	Group 2 (predicted nonviable myocardium)	p Value (ANOVA)
Exercise thallium-201	n = 6	n = 9	
Qualitative uptake (61 abnormal segments)			
Abnormal segments/pt	2.8 ± 2.4	5.0 ± 1.1*	
Stress uptake	1.4 ± 0.8	0.5 ± 0.7*	< 0.0001
Redistribution	1.7 ± 0.6	0.5 ± 0.6*	
Reinjection	1.7 ± 0.8	0.5 ± 0.7*	
Quantitative uptake			
Stress uptake (%)	44 ± 13	28 ± 9*	< 0.0001
Redistribution (%)	52 ± 16†	27 ± 9*	
Reinjection (%)	57 ± 16†	27 ± 10*	
Radionuclide angiography	n = 9	n = 13	
LVEF (%)			
Early	57 ± 13	53 ± 10	< 0.0001
Late	66 ± 10‡	46 ± 8*	
Regional wall motion			
Worst segment			
Early	0.9 ± 1.0	−0.3 ± 0.5*	< 0.0001
Late	1.8 ± 0.9‡	−0.3 ± 0.4*	

*p < 0.05, Group 1 versus Group 2. †p < 0.05 versus stress uptake. ‡p < 0.05, early versus late. Data presented are mean value ± SD or number of patients. Abbreviations as in Table 2.

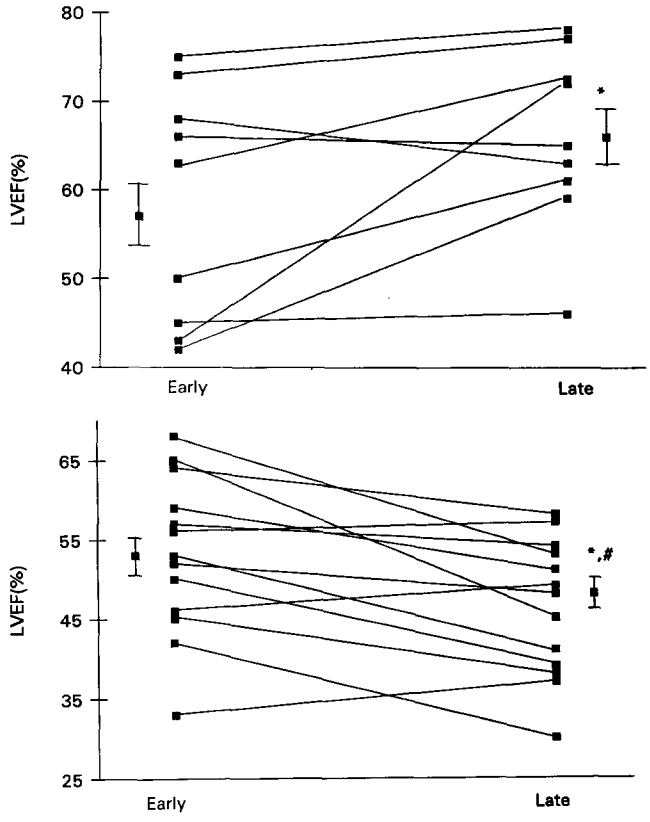

Figure 1. Early and late left ventricular ejection fraction (LVEF) in patients with a follow-up radionuclide angiogram (Group 1 **[top]**, Group 2 **[bottom]**). Individual data and mean value ± SEM are presented **(vertical bars)**. *p < 0.01, early versus late ejection fraction. #p < 0.0001, Group 1 versus Group 2.

jection, counts in the infarct zone increased in Group 1 but remained unchanged in Group 2. All Group 1 patients had at least one segment with a ≥15% increase on redistribution or reinjection. Four patients reached this level on redistribution, two only after thallium-201 reinjection.

Late radionuclide angiography (Table 3, Fig. 1 and 2). There were 22 patients who underwent late radionuclide angiography at 64 ± 95 days after infarction. In 14 patients, the repeat study was performed before discharge (8 ± 2 days after infarction), whereas in the other 8 it was performed between 35 and 270 days. In Group 1, left ventricular ejection fraction (Fig. 1, top) and infarct zone wall motion (Fig. 2, top) increased between initial and late scans, whereas they tended to deteriorate in Group 2 (Fig. 1, bottom and Fig. 2, bottom). Of the five Group 1 patients who had severe initial rest thallium-201 defects with redistribution on the delay scan, four had early and late radionuclide studies. Ejection fraction changes mirrored the total group, increasing from 51 ± 9% to 61 ± 11% (p = 0.07). Of 13 abnormally contracting segments in these four patients, wall motion improved from 1.0 ± 0.9 to 1.8 ± 0.8 (p < 0.0001).

Of the nine Group 1 patients with early and late wall motion studies, five had at least one akinetic segment (n = 11 segments) on the early study. Wall motion improved in 9 of 11 akinetic segments on the late study (mean improving from 0 ± 0 to 1.73 ± 1.19, p < 0.0001). In contrast, all 13 Group 2 patients with early and late wall motion studies had at least one akinetic or dyskinetic segment (n = 42 segments). The mean wall motion score in these 42 segments was −0.31 on both early and late studies.

Patients with revascularization (Table 4). In 15 of the 17 patients with revascularization, radionuclide angiography was repeated after revascularization. The initial mean ejection fractions in both subgroups were similar. After revascularization, there was an improvement in ejection fraction and infarct segment wall motion in Group 1 but a deterioration in Group 2.

Discussion

Many patients with acute myocardial infarction demonstrate prolonged myocardial dysfunction or stunning despite adequate reperfusion (1). With the widespread use of thrombolytic therapy for the treatment of acute infarction, early and accurate assessment of residual myocardial viability in the infarct territory after reperfusion would provide important clinical information. Identification of patients with and without viable myocardium could well lead to better classification of patients for appropriate noninvasive and invasive testing.

Current study. These data indicate the utility of rest–redistribution thallium-201 scintigraphy in detecting viable myocardium in the infarct zone in patients within 48 h of a myocardial infarction. Our Group 1 patients with predicted viable myocardium had a better early and late left ventricular ejection fraction and infarct-related regional wall motion as

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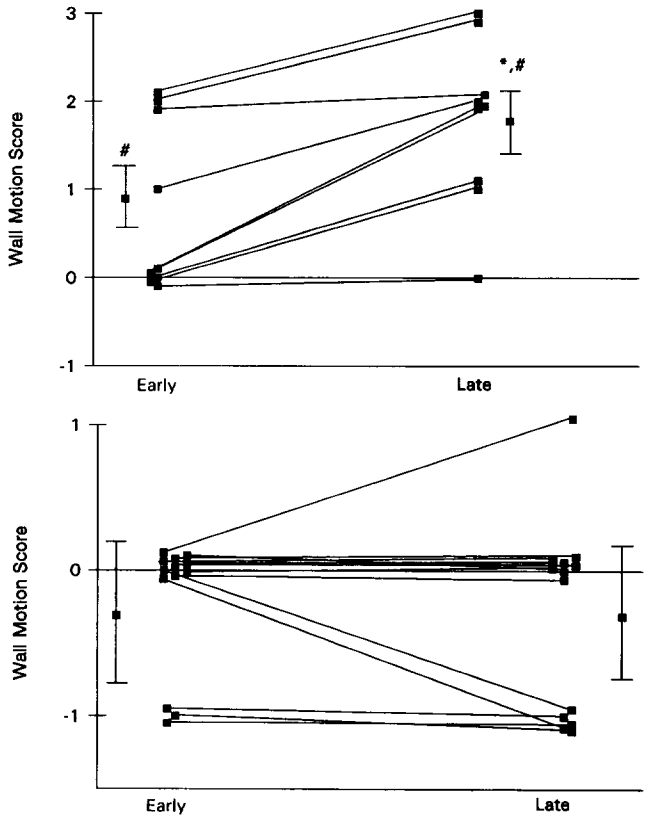

Figure 2. Early and late infarct zone wall motion scores for patients with a follow-up radionuclide angiogram (Group 1 **[top]**, Group 2 **[bottom]**). Individual data and mean value ± SEM (**vertical bars**) are presented. *$p < 0.01$, early versus late infarct zone wall motion scores. #$p < 0.001$, Group 1 versus Group 2.

well as increased thallium-201 uptake in the infarct zone on stress–redistribution–reinjection thallium-201 scintigraphy than our Group 2 patients predicted to have nonviable myocardium. In the subgroup of patients with revascularization, only those patients predicted to have viable myocardium on the basis of rest thallium-201 scintigraphy had improved global and regional ventricular function.

Table 4. Revascularization Results

	Group 1 (predicted viable myocardium)	Group 2 (predicted nonviable myocardium)	p Value (ANOVA)
Revascularization	11	6	
Radionuclide angiography	9	6	
LVEF (%)			
Pre-op	56 ± 13	59 ± 9	< 0.002
Post-op	66 ± 11*	49 ± 7†	
Regional wall motion			
Worst segment			
Pre-op	0.8 ± 0.5	−0.3 ± 0.3†	< 0.005
Post-op	1.8 ± 0.9*	−0.7 ± 0.5†	

*$p < 0.05$, preoperative (pre-op) versus postoperative (post-op). †$p < 0.05$, Group 1 versus Group 2. Data presented are mean value ± SD or number of patients. Other abbreviations as in Table 2.

Early wall motion results in this study suggest that rest thallium-201 scintigraphy identified smaller infarcts with viable myocardium in the infarct zone in Group 1 than in Group 2. Pathologic studies have confirmed that hypokinetic wall motion is usually associated with a nontransmural extent of infarction, whereas akinetic wall motion is more likely to be seen with transmural infarction (15). However, because stunned myocardium can cause akinetic wall motion early after infarction when the myocardium is viable, we used either stress–reinjection thallium-201 scintigraphy or late radionuclide angiography to confirm viability.

Thallium-201 scintigraphy for viability. With exercise thallium-201 scintigraphy, mild persistent defects represent viable myocardium rather than scar. Gibson et al. (16) showed that 57% of mild fixed defects on exercise scintigraphy exhibited improved function after revascularization. In patients with chronic coronary disease, mild thallium-201 defects after exercise demonstrate glucose metabolism by positron emission tomography, consistent with viability (5,17). In severe fixed defects, reinjection thallium-201 imaging has been used to detect viable myocardium (5,17). Dilsizian et al. (3,17) and Bonow et al. (5) demonstrated that myocardial regions showing enhanced thallium-201 uptake after reinjection had improved regional wall motion after angioplasty (3) and increased glucose metabolism (5,17). In contrast, persistent defects after reinjection were associated with persistently abnormal regional wall motion (3) and nonviability by positron emission tomography (5,17). Our Group 1 patients who exercised after infarction had mild to moderate perfusion abnormalities that improved with thallium-201 reinjection, consistent with viable myocardium. By contrast, our Group 2 patients who exercised had severe defects that did not improve after reinjection, suggesting severe infarction without residual viability.

Change in ventricular function for viability. Improvement in regional ventricular function over time or after revascularization is a well tested method used to detect viable myocardium (3,8,16,18–20). Group 1 patients who had late radionuclide angiography showed improved global and regional function consistent with persistent viability as opposed to Group 2 patients who demonstrated deterioration of left ventricular function, suggesting nonviable myocardium. When segments with severe wall motion abnormalities (akinetic or dyskinetic) were compared, similar differences were found between Groups 1 and 2, indicating that even with marked regional dysfunction our classification of viability was useful. The data after revascularization confirm the test data after infarction.

Previous studies. Previous studies (21–23) have examined the role of rest thallium-201 scintigraphy in acute and chronic coronary syndromes. Rest perfusion abnormalities are present early after infarction. In patients with severe coronary disease, rest thallium-201 defects with redistribution are associated with preserved wall motion (24) and an increase in left

ventricular ejection fraction after revascularization (14). It was recently demonstrated that rest thallium-201 scintigraphy was predictive of improved regional function after revascularization in patients with multivessel coronary disease and depressed ejection fraction (18,25) and compared reasonably well with stress–redistribution–reinjection imaging (26).

Postinfarction dysfunction. The pathophysiology of the wall motion abnormalities in our patients is probably multifactorial. In a clinical model of hibernation, Vanoverschelde et al. (27) evaluated patients in whom an occluded coronary artery was supplied by collateral vessels and in whom there was no evidence of previous infarction. Some of the patients had normal, whereas others had markedly abnormal, regional wall motion. Using positron emission tomography, these investigators showed that in patients with chronically depressed regional ventricular function in whom a relative perfusion abnormality was present (i.e., hibernation), absolute myocardial blood flow and myocardial oxygen consumption in the dysfunctional zone were normal. These findings were in distinction to the premise of hibernation in which a dysfunctional segment is chronically hypoperfused (27). The coronary flow reserve in the region was impaired compared with patients with normal systolic function, suggesting that the abnormal mechanical function resulted from repetitive episodes of ischemia with persistent stunning rather than hibernation (27). Thus, without measures of absolute myocardial blood flow in our patients, it is difficult to characterize their mechanical abnormality. Further complicating the classification is the fact that all our patients had an infarction in the region of interest.

Whether the segments with infarction had elements of hibernating or stunned myocardium, the initial distribution of thallium-201 on the rest study was most likely related to myocardial blood flow. In an animal model of postischemic dysfunction, Sinusas et al. (28) demonstrated good correlation between relative thallium-201 uptake in the ischemic zones and myocardial blood flow during a low flow state (hibernation) and after occlusion–reperfusion (stunned myocardium). Thus, it is likely that the extraction of thallium-201 is not altered by either stunned or hibernating myocardium. After the initial images, there is a continuous exchange of thallium-201 between the viable myocardial cells and the blood pool. Redistribution at rest will occur in a segment that was underperfused initially but still viable (25). A defect will remain persistent if the segment is irreversibly infarcted, if it is supplied by a severely stenotic vessel such that there is not enough time for redistribution or if it represents an area of mixed necrosis and viable myocardium (25). Stress imaging with thallium-201 reinjection would differentiate these types of patients (26).

Study limitations. When thallium-201 is given immediately after thrombolysis, its uptake in the infarct zone overestimates viability (29,30). In the current study, all rest studies were performed at least 24 h after infarction. When using late radionuclide angiography to confirm viability, an improvement in wall motion was consistent with viable myocardium. However, wall motion within the infarct zone may improve because of a reduction in acute tethering effects (31) or changes in local loading conditions as a result of remodeling (32). Failure of the wall motion to improve may simply imply persistent stunning. It may take several weeks for contraction to return to normal after reperfusion (33). The majority of follow-up studies were performed before hospital discharge, raising the possibility that in Group 2 wall motion was still impaired as result of stunning and that it might improve if studied later. However, wall motion improvement in Group 1 should also have been underestimated by early imaging. Accordingly, the difference between Groups 1 and 2 would not have been likely to change significantly with later imaging. Further, there was no difference in the degree of improvement in wall motion between the 14 patients who were restudied before discharge and the 8 who were studied >1 month after infarction. Thus, it is again unlikely that the early timing of the follow-up radionuclide angiogram affected our results. We cannot exclude the possibility that a number of Group 2 patients, despite severe regional wall motion abnormalities and fixed perfusion abnormalities, may have had viable myocardium that was not identified by rest thallium-201 scintigraphy. However, it should be noted that six of these patients had revascularization and still had no demonstrable improvement in ventricular function postoperatively.

Exercise stress with thallium-201 reinjection has been compared with positron emission tomography, with an excellent relation between viability defined by both techniques (5). Although patients with less severe thallium-201 defects on rest scintigraphy early after a myocardial infarction would be likely to have less severe abnormalities during exercise several days later, this finding has not been previously demonstrated. In patients with chronic left ventricular ischemic dysfunction, Dilsizian et al. (26) compared the results of rest–redistribution with exercise–redistribution–reinjection thallium-201 scintigraphy. They found some discordance in the classification of irreversible defects as viable versus nonviable by both techniques, with an underestimation of viability by the rest study (26). Several factors could have caused a disparity between our rest and exercise studies, including ischemia during exercise in the infarct zone that was not manifested at rest, ischemia outside the infarct zone during exercise as a result of the presence of multivessel coronary disease, reocclusion after thrombolytic therapy or angioplasty, expansion of the infarct zone and changes in perfusion related to revascularization and the recovery of regional function.

These data are preliminary in that the number of patients with severe regional wall motion abnormalities, in whom viability is a pertinent issue, was small. In addition, the findings would have been strengthened had all patients had viability confirmed by the same method after infarction. Using the thallium-201 scan to detect viability in a clinical setting is less meaningful in patients with preserved wall motion (viable by definition) and those who are not candidates for revascularization procedures (i.e., a widely patent infarct-related vessel). Therefore, confirmatory studies in patients early after infarction who have akinetic/dyskinetic wall motion and are being considered for revascularization would be desirable. In a group

Table 5. Common Clinical Variables Measured in Groups 1 and 2

	Group 1 (predicted viable myocardium)	Group 2 (predicted nonviable myocardium)	p Value
CK <1,000 (IU/liter)	9/15	4/16	0.11
Non-Q wave MI	4/15	1/16	0.29
Normal LVEF	8/15	8/16	0.86
CK <1,000 + non-Q MI	3/15	1/16	0.55
CK <1,000 + non-Q MI + normal LVEF	1/15	1/16	0.49
Any variable (CK <1,000 or non-Q MI or normal LVEF)	13/15	9/16	0.14

Data presented are number of patients. MI = myocardial infarction; other abbreviations as in Tables 1 and 2.

with viable myocardium, the need for revascularization would also depend on demonstrable ischemia secondary to a significant coronary stenosis. The current study does not purport to demonstrate that patients with viability (Group 1) should undergo revascularization. Wall motion and ejection fraction may have improved in these patients spontaneously without revascularization. The decision for revascularization was made independently of the rest thallium-201 results.

Future studies. The place of the rest scan in the thrombolytic era needs to be defined by larger studies (Table 5). The rest scan should not replace the predischarge exercise study because the latter yields important prognostic information and can diagnose myocardial ischemia (34). It appears that pharmacologic stress testing with adenosine (35) or dipyridamole (36–39) can be performed safely after infarction and can yield important prognostic information. In patients in stable condition, pharmacologic stress testing may yield more information concerning ischemia outside the infarct zone than rest imaging. A comparison of these tests would be of interest. A comparison of the rest thallium-201 scan to other readily available data to assess viability should be attempted in larger studies. In our patients, readily available clinical data did not differentiate the two groups.

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